

Recover
Detection

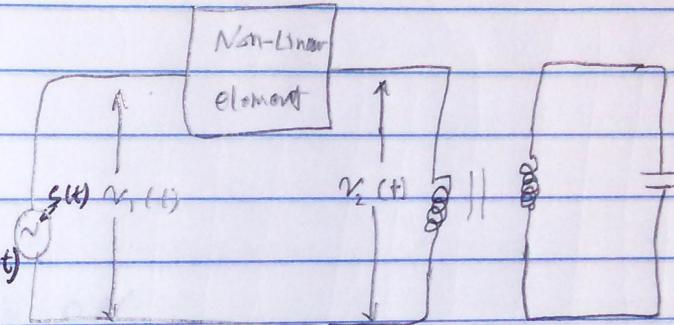
Demodulation of AM Waves:

$$\underset{\text{AM wave}}{S(t)} = \underset{\text{message}}{A_c [1 + k_e m(t)]} \cdot \underset{\text{baseband signal}}{\cos(2\pi f_c t)}$$

① Square-Law Detector:

$$V_2(t) = \alpha_1 V_1(t) + \alpha_2 V_1^2(t)$$

$$V_2(t) = \alpha_1 A_c [1 + k_e m(t)] \cos(2\pi f_c t)$$



$$+ \alpha_2 A_c^2 [1 + 2k_e m(t) + k_e^2 m^2(t)] \cos^2(2\pi f_c t)$$

$$\frac{1}{2} [1 + \cos(4\pi f_c t)]$$

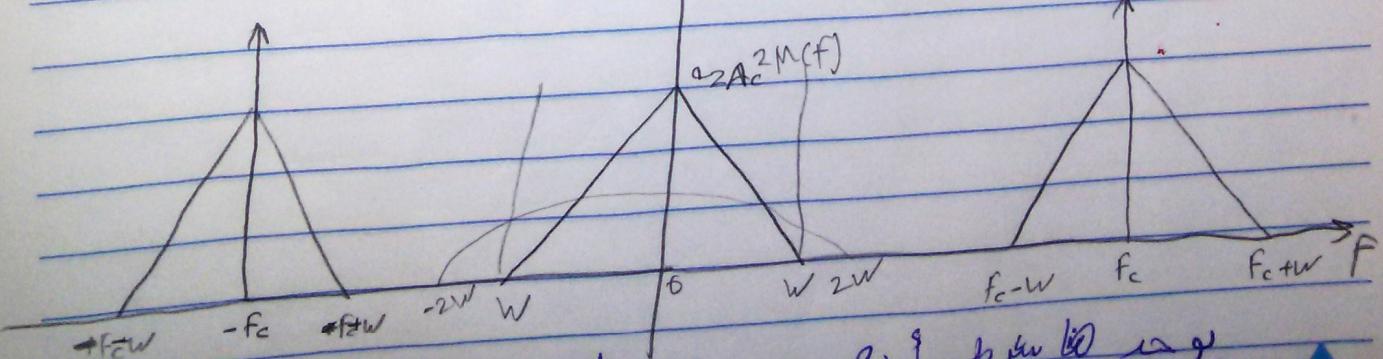
$$V_2(t) = \alpha_1 A_c [1 + k_e m(t)] \cos(2\pi f_c t) + \frac{1}{2} \alpha_2 A_c^2 + \frac{1}{2} \alpha_2 A_c^2 k_e m(t)$$

$$+ \frac{1}{2} \alpha_2 A_c^2 k_e^2 m^2(t) + \frac{1}{2} \alpha_2 A_c^2 [1 + 2k_e m(t) + k_e^2 m^2(t)] \cos(4\pi f_c t)$$

Low-pass
Filter

(This can be all merged into 1, but I'll keep it)

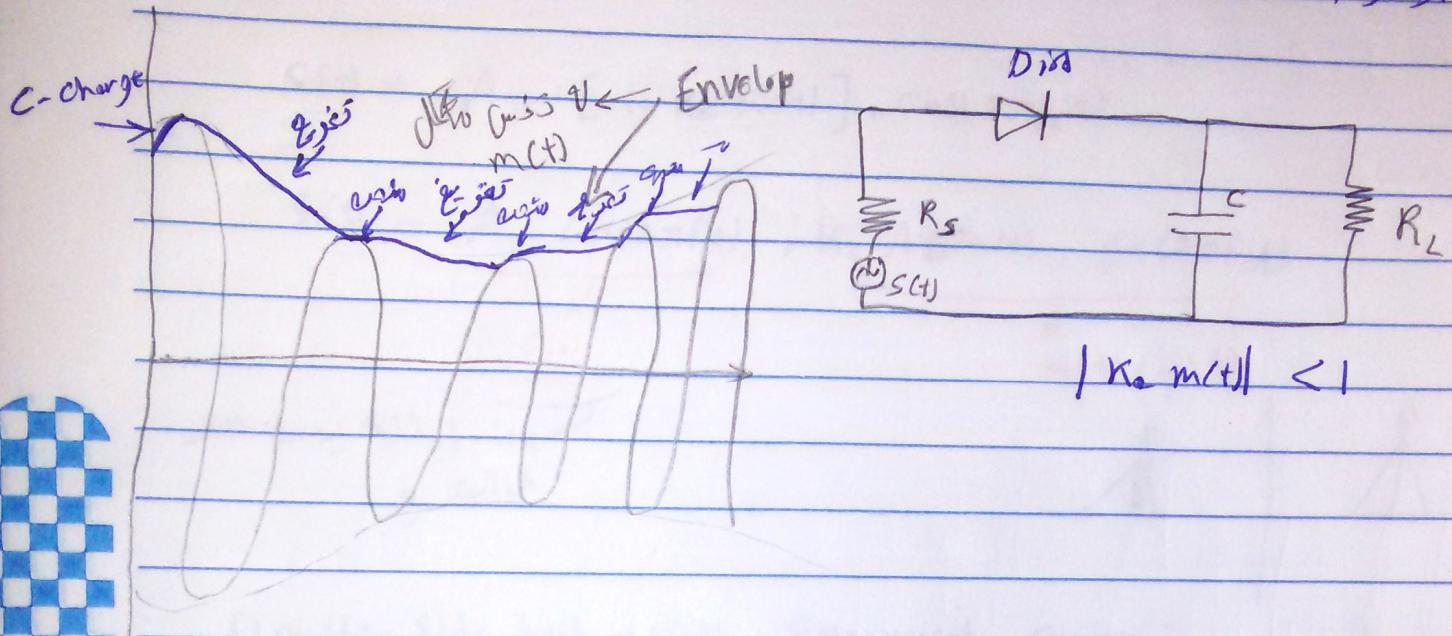
$$|V_2(t)|$$



$|k_e m(t)| < 1$
 $m^2(t) \leq 1$ (This is so)

(2) Envelope Detector

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$s(t) \rightarrow$ high value

$C \rightarrow$ charging

Diode ON

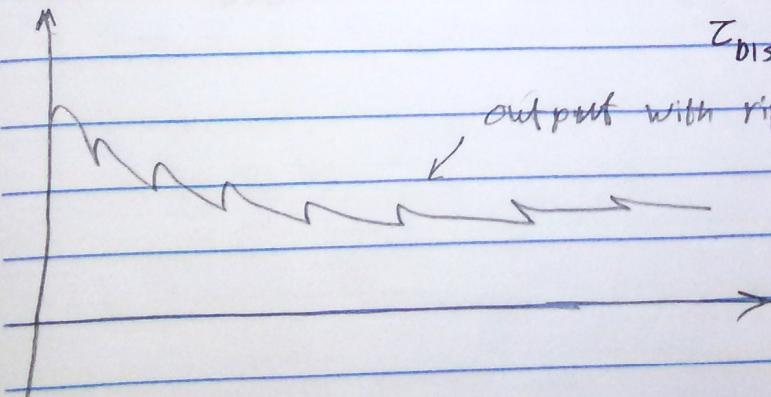
$$\text{Charging time} = R_S C < \frac{1}{F_c}$$

$C_c \rightarrow$ very small

$$\text{Discharging time} = R_L C < \frac{1}{W}$$

$$Z_{DIS} \rightarrow \infty$$

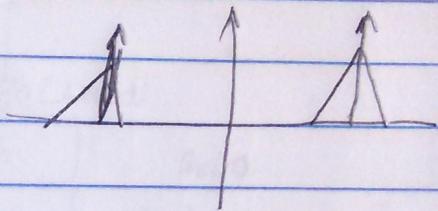
output with ripple



$$S(t) = A_c [1 + k_m m(t)] \cdot \cos(2\pi f_c t)$$

$$S(t) = \underbrace{A_c \cos(2\pi f_c t)}_{c(t)} + \underbrace{k_m A_c m(t)}_{m(t) \cdot c(t)} \cos(2\pi f_d t)$$

$c(t)$
Carrier
wave, $m(t)$, $c(t)$

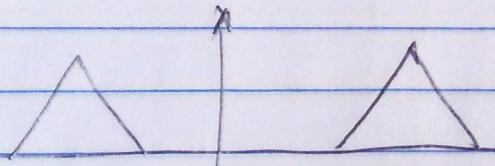


Double-Side band - with Suppressed Carrier

$\cos(\omega_c t)$ as Carrier

$\sin(\omega_c t)$

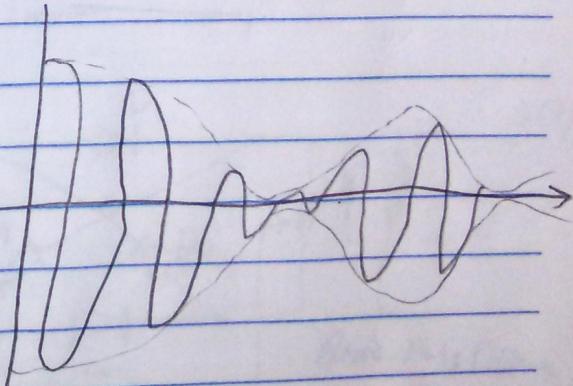
$$S(t) = c(t) \cdot m(t)$$



$$S(t) |_{BSB,SC} = A_c m(t) \cos(2\pi f_c t)$$

DSB-SC in Frequency Domain

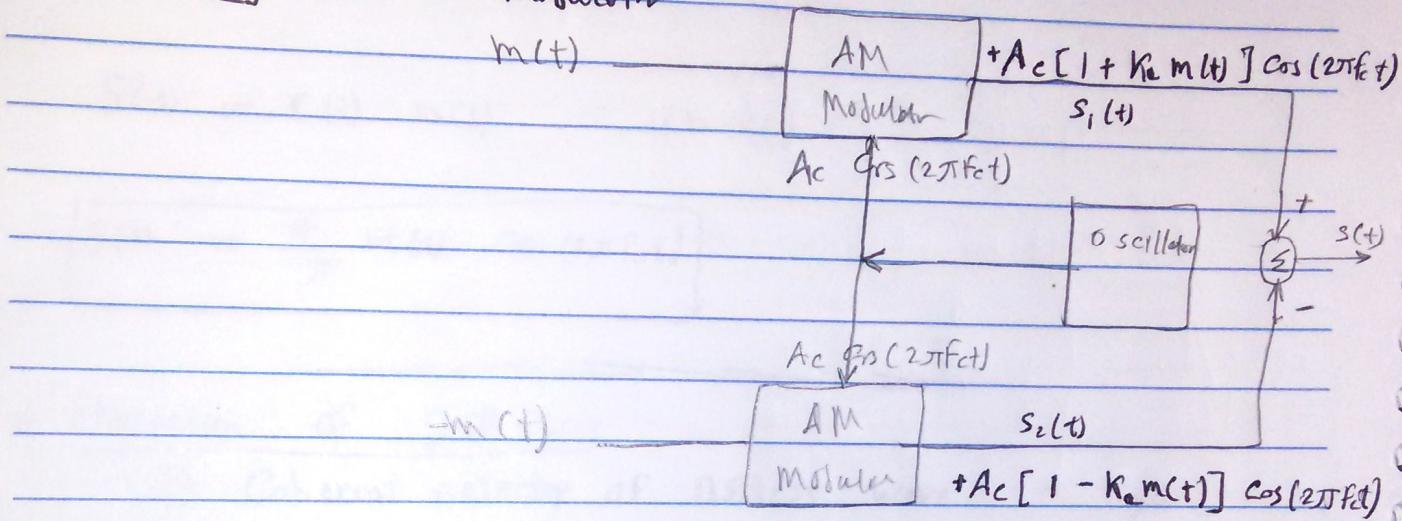
BSB,SC



DSB-SC in time Domain

① Modulator For DSB-SC:

① balanced modulator



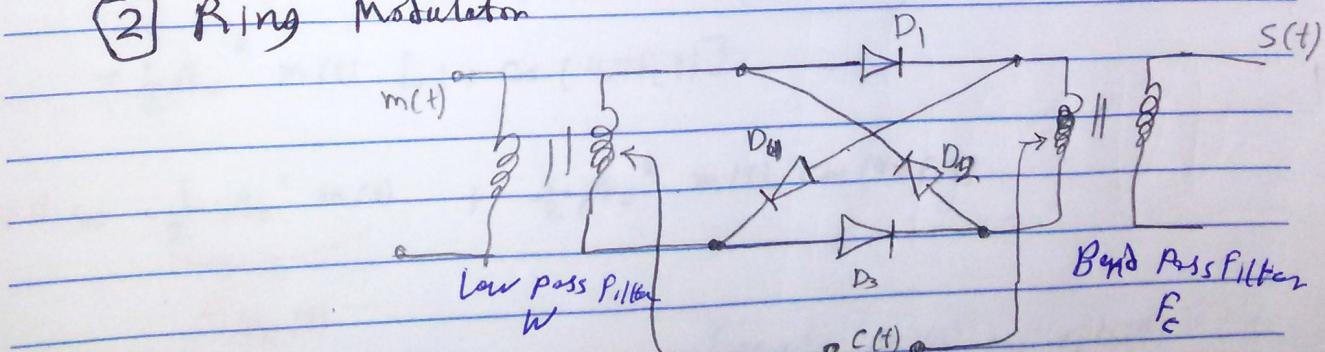
$$s_1(t) = A_c [1 + k_m m(t)] \cos(2\pi f_c t)$$

$$s_2(t) = A_c [1 - k_m m(t)] \cos(2\pi f_c t)$$

$$s(t) = s_1(t) - s_2(t)$$

$$s(t) = 2 A_c k_m m(t) \cos(2\pi f_c t)$$

② Ring Modulator

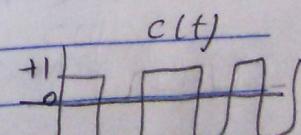


$c(t) \rightarrow \text{positive}$

→ D_1, D_3 ON
→ D_2, D_4 OFF

$c(t) \rightarrow \text{negative}$

→ D_2, D_4 ON
→ D_1, D_3 OFF



pulse train

$$C(t) = \frac{q}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2^{n-1}} \cos [2\pi f_c t + (2n-1)]$$

$$S(t) = C(t) \cdot m(t) \quad (n=1)$$

$$S(t) = \frac{q}{\pi} m(t) \cos(2\pi f_c t)$$

* Detection of DSB-SC:

① Coherent detector of DSB-SC wave

$$S(t) = A_c m(t) \cos(2\pi f_c t)$$

2W

$$S(t) \rightarrow \begin{cases} \text{Product Modulator} \\ \text{VCO} \end{cases} \xrightarrow{\text{Low pass Filter}} V_o(t)$$

$$S(t) = A_c m(t) \cos^2(2\pi f_c t)$$

$$= \frac{1}{2} A_c^2 m(t) [1 + \cos(4\pi f_c t)]$$

$$V(t) = \frac{1}{2} A_c^2 m(t) + \frac{1}{2} A_c^2 m(t) \cos(4\pi f_c t)$$

↓ V_o(t)

local oscillator $\cos(2\pi f_o t)$

$$A_c \cos(2\pi f_c t + \phi)$$

$$A_c \cos(2\pi(f_c + \Delta f)t)$$

ϕ local
f_c 91

Detection 100% efficiency

Phase error

$$c(t) = A_c' \cos(2\pi f_c t + \phi)$$

$$v(t) = A_c A_c' \cos(2\pi f_c t) \cos(2\pi f_c t + \phi), m(t)$$

$$= \frac{1}{2} A_c A_c' m(t) [\cos(4\pi f_c t + \phi) + \cos \phi]$$

$$v_o(t) = \frac{1}{2} A_c A_c' m(t) \cos \phi$$

$\phi = 0 \rightarrow$ out ✓
 $-90^\circ \rightarrow$ out 0 ✗

Report → Frequency error